

**“Industry Survey of Nanomanufacturing Trends and
Commercialization Activities in the U.S.”**

Final Report by

**Dr. Manish Mehta, Principal Investigator
National Center for Manufacturing Sciences (NCMS)
Ann Arbor, MI**

NSF Award: DMI-0305091

**Sponsor Representatives:
Dr. Julie Chen and Dr. Mihail Roco
NSF Nanomanufacturing
National Science Foundation
4201 Wilson Boulevard, Rm. 550
Arlington, VA 22230**

April 5, 2004

Preface

Background:

The National Center for Manufacturing Sciences (NCMS) proposed to the NSF in early 2003 to undertake a study of efforts within the conventional industry (such as metallic and polymeric materials, machine tools, and automotive/aerospace/healthcare end users) trends, interests and activities (R&D, production, plans for the future) towards development and commercialization of nanomanufacturing technologies, as a supplementary activity to the NSF Workshop on “Three-Dimensional Nanomanufacturing: Partnering with Industry”, to be conducted in conjunction with the NSF Design and Manufacturing Grantees Conference, Birmingham, AL, in January 2003.

The NCMS Nanomanufacturing Industry Survey was approved as NSF sub-contract # **DMI-0305091**, duration April 1, 2003 to April 1, 2004. The survey was performed as a supplemental activity to the primary NSF award to Northeastern University as under:
Proposal Number 0237650

Proposal Title Workshop: Three Dimensional Nanomanufacturing- An Industry Perspective; January 5-6, 2003, Birmingham, AL

Received on 07/22/02

Principal Investigator Ahmed Busnaina

Co-PI(s) Carol Barry, Glen Miller, Ramana Reddy

Institution: Northeastern University

Program Information

NSF Division of Design, Manufacturing & Industrial Innovation

Program Name: Nanomanufacturing

Program Officers: Julie Chen/ Charalabos C. Doumanidis

Telephone (703) 292-7088

E-Mail jchen@nsf.gov

Survey Objective:

The objective of the NCMS-NSF Nanomanufacturing Industry Survey was to determine and assess some key aggregate trends and concerns about nanomanufacturing in the US manufacturing industry, via a targeted questionnaire, and to identify some success stories or in-progress efforts in applications of nanomanufacturing nearing commercialization. This information was regarded as valuable input to the NSF’s current Grand Challenge in Manufacturing at the Nanoscale program.

It was anticipated that the survey would reveal an important “snapshot” of interest, attitudes/perceptions, R&D activities and plans of conventional manufacturing industry towards manufacturing at the nanoscale by yielding information on:

- Key industry trends and attitudes (industry drivers, investments, staffing, portfolio, barriers, etc.) and plans for the next 5-10 years, and how they might impact the supplybase

- Current and near-term success stories in nanomanufacturing and product realization
- The nature of the impact of nanomanufacturing technologies and products across different industry segments

Methodology:

NCMS drafted the interactive survey questionnaire (with input from NSF) and launched the online survey during the period April – September 2003, initially soliciting its corporate membership of nearly 150 small, large and medium organizations through its monthly periodicals and newsletter publications. Next, NCMS targeted strategic and technology planning executives within its manufacturing industry partners at large, numbering nearly 6000 individuals from industry, government and academia, including about 88 companies known to be focused on nanotechnology developments. The solicitations invited those executives involved in nanomanufacturing technology developments to respond to the on-line survey questionnaire accessible at the NCMS corporate website (www.ncms.org). Respondents were also encouraged to share anecdotal information or key concerns, as well as success stories of their developments.

Survey raw data were processed and analyzed using Microsoft Excel. Survey statistics, trends and responses were illustrated for ease of interpretation.

Potential Uses of NCMS-NSF Nanomanufacturing Survey Information:

- The at-a-glance survey results provide a useful snapshot of the industry profile for promoting nanomanufacturing technology awareness within the government, general industry and the public.
- Develop strategic and operation guidelines as input for the draft Report on NSF Grand Challenge on Manufacturing at the Nanoscale.
- Provide valuable, representative information for the government's program assessment, and lessons learned – such information would be important in the evaluation of the National Nanotechnology Initiative (NNI), and may help NSF and collaborating NNCO/NSET agencies to review and reshape their strategy for the future in promoting nanomanufacturing in North America.
- Develop focused technology awareness and training programs and curricula for future events and industry briefings on nanotechnology.

Discussion and Recommendations:

The NCMS-NSF Nanomanufacturing Industry Survey results indicate that early commercialization developments of nanotechnology have been in catalysis, coatings, electronic devices, sensors, medical diagnostics and high performance materials. The industry overwhelmingly favors a significant government role in the development of nanomanufacturing. The key barriers perceived by industry include the widespread perception amongst the public that nanotechnology is far from reaching the market – this points to the need for more public awareness on nanotechnology, its societal benefits, and relationship to economic growth. Other barriers include the lack of investment capital for

more rapid growth and commercialization scale-up for multiple end user markets, intellectual property, high process cost, and poor process scalability and complexity.

Of particular note, two key factors, (1) foreign competition and (2) environmental and safety concerns were not indicated as higher importance barriers. We believe this “anomaly” is due to the majority of respondents being small businesses and startups that have not yet reached significant sales volumes and product manufacturing using nanotechnology that would require making investments in addressing environmental compliance requirements (such as safe disposal and handling of raw materials and by-products).

The survey findings clearly indicate that it is the industry’s collective opinion that the government needs to play a major role in addressing the barriers by stimulating R&D collaborations, providing access to capital intensive R&D facilities, and sharing advances and awareness within the larger industry and public, thereby assuring that the enormous benefits of nanotechnology will be realized quickly. The goals and applications of many nanotechnology developments are unique and too long term for industry and the market to take an immediate leadership role. Due to the highly inter-disciplinary and phenomenological nature, the development of nanotechnology products and processes requires creating collaborative engineering-focused teams of chemists, physicists, biotechnologists and engineers to tackle the technology challenges, and the cooperating funding agencies will need to be organized to leverage and foster this teamwork. Only a small percentage of survey respondents indicated they have adequate access to development facilities. This calls for widespread and simplified access to enabling world class research and production capabilities, training and facilities infrastructure, which must be in place for the emerging industry to rapidly capitalize on innovations in nanotechnology. These will help nurture the national nanotechnology industry and provide the basis for large-scale industrialization of the technologies. It is recommended that follow-up industry “pulse” or aggregate surveys be conducted and broadly disseminated on an annual basis as the technology evolves and matures in North America.

Conclusion:

Strategies to achieve significant compression of lead time and resources for commercialization are urgently needed to maintain the United States’ leadership in nanotechnology products and processes, and for the industry to be regarded as an important source of future manufacturing and high technology jobs at a time of increasing pace of technological and market change. Parallel development of research and commercial products, and leveraging of synergy among industry, university, and government partners are required, along with effective assessment and feedback mechanisms as the industry evolves and matures. Memes advanced by the industry will help improve collaboration, problem-solving, consensus-building and help unite nanotechnologists on common terms, concepts and visions for the industry, thereby accelerating innovation.

Acknowledgement:

NSF DMII representatives: Dr. Mihail Roco, Senior Advisor to NSF, Dr. Julie Chen, NSF Program Manager and Dr. Haris Doumanidis, (former NSF Program Manager).

NCMS MIS and Knowledge Solutions staff for assistance with launching the survey and with illustrations.

Relevant Presentations:

1. NSF-Northwestern University Workshop on Convergence Technologies, Washington DC, September 22, 2003.
2. National Nanotechnology Initiative Conference Manufacturing Workshop, Washington DC, March 31, 2004.

Summary of Results

NCMS-NSF Nanomanufacturing Industry Survey

The NSF commissioned the NCMS to conduct the nation's first industry "pulse" survey amongst conventional manufacturing organizations to identify trends and concerns for addressing in the Grand Challenge on Manufacturing at the Nanoscale. The survey invitation was delivered electronically during April – September 2003 to over 6000 manufacturing executives in the metalworking and polymer processing industries, including 88 targeted nanotechnology companies. The results presented below are for responses of 81 senior level executives with technology strategy and R&D responsibility at small to large corporations. The complete survey results are provided and discussed below:

1. Which industries are you involved in?

Nanotechnology developments are being targeted for use in diverse industries by the researchers. Top seven end uses are:

- 35% for Electronics
- 33% for Coatings
- 32% for Devices and sensors
- 19% for Automotive applications
- 18% for Raw materials supply
- 15% for Biotechnology/Biomedical
- 13% for Polymers and petrochemicals

2. How fast is your industry/market changing?

Nearly two-thirds (63%) of executives feel that their business and market(s) are changing rapidly, thereby impacting their organization's strategy. Less than 10% felt that change is slow in their business.

3. How is your company/organization changing its strategy to accommodate nanomanufacturing technology developments?

Only 16% of respondents felt their organizations are coping well with strategy changes (e.g., technology/product portfolio, investments, market focus, etc.), and only 2% felt they are coping poorly; the majority (82%) appear to be struggling with developing and implementing strategies for nanotechnology products.

4. What is your company/organization's capacity for pursuing development of nanomanufacturing technologies?

Over 50% of respondents felt their organizations do not possess sufficient internal capacity to pursue nanomanufacturing developments. In cross-correlating the data, it appeared that larger companies and start-up companies with alliances with universities fared better and have greater capacity for taking risks in nanotechnology-focused investments.

5. Is your company/organization's infrastructure (e.g., lab space, processing equipment, test and diagnostics capability, etc.) adequate for nanomanufacturing?

18% felt infrastructure is sufficient

9% felt infrastructure is insufficient

75% felt critical infrastructure and access are lacking for nanomanufacturing developments

6. Rate your company/organization's urgency for commercializing new nanomanufacturing advances into product.

48% feel their organizations have placed high priority on commercialization

9% feel their organizations have placed low priority

43% feel organizations feel commercialization is placed on medium priority

Companies that are startups (often with venture capital) tended to place high priority on commercialization of nanomanufacturing developments.

7. Is your company/organization developing nanotechnology products internally or via external collaborations (with customers, suppliers, academia, national labs, trade groups, etc.)?

6% - Mostly collaborative development

3% - Strictly internal efforts

91% - Combination of internal and collaborative work

8. How many staff members are involved in your company/organization's nanomanufacturing activities?

42% - Less than 10 staff

40% - 11-30 staff

12% - 31-50 staff

6% - Over 50 staff

2 companies stated their nanotech development staffing exceeds 100 persons.

9. When does your company/organization expect to introduce commercial products incorporating nanotechnologies?

28% - Already marketing nanotechnology products
15% - Will commercialize within 1 year
26% - Will commercialize within 3 years
20% - Expect to commercialize within 3-5 years
11% - Commercialization will take longer than 5 years

10. What types of nanomanufacturing technology products are being pursued in your organization?

A broad range and functionality of nanotechnology products have or are reaching commercialization. Top five product categories are:

20% - Coatings
15% - Sensors
15% - Other (catalysis products, electronic devices, optical displays, high performance materials)
8% - Polymers for specialty applications
7% - Film and membrane products

19% executives chose not to provide this information

11. What is your opinion of the government's role in promoting nanomanufacturing technologies?

2% feel the government should assume all risks in nanotechnology developments
51% feel government should invest heavily and offer incentives to industry
32% feel government should only support pre-commercial nanomanufacturing activities
13% feel that industry should lead developments and government provide funds
2% feel government involvement is not needed in nanotechnologies

12. What are the key challenges facing the US nanomanufacturing industry?

Key challenges have to do with the widespread industry and public perception that nanotech is far from reaching the market – this points to the need for more public awareness on nanotechnology, its societal benefits, and relationship to economic growth. Other barriers include intellectual property, process cost, scalability and complexity. Of particular note, foreign competition was not

considered an important barrier, nor was environmental and safety concerns indicated as important barriers.

Top six industry concerns indicated:

15% feel nanotechnology products are a long way from commercialization

14% feel there is insufficient investment capital for nanotechnology

12% feel intellectual property issues impede commercialization progress

11% feel process scalability is an area of challenge

11% feel the cost of processing is too high

9% feel societal benefits of nanotechnology are not yet recognized